Observations of the Effect of Diet on Shell Coloration in the Red Abalone, *Haliotis rufescens* Swainson

by

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(Plate 6)

The color of the ostracal shell layer of the red abalone, Haliotis rufescens Swainson, 1822, is typically a "dull brick red" (Cox, 1960). In many specimens the continuity of the general red aspect may be interrupted by zones of pink, white or green coinciding in position with the growth lines. Variation of shell color may be extreme; the writer has collected many specimens with predominantly or purely white shells. The feature of variable shell color occurs, to a greater or lesser degree, in all California abalones and has been reported to occur also in Japanese forms (Ino, 1952). Study has been made of the effect of diet on shell coloration in the topshell, Turbo cornutus (Solander, 1788), by the same investigator (Ino, 1949, 1958).

Coloration of shells in mollusks has in several other instances been linked with diet. Perhaps most notable of these is the demonstration that a diet of Mytilus edulis Linnaeus, 1758, is accompanied by secretion of brown shell in Purpura lapillus Linnaeus, 1758, and that feeding upon barnacles (Balanus balanoides and Chthamalus stellatus) results in deposition of white shell material (Moore, 1936). Purpura is, however, a carnivorous mollusk while the abalones and topshells are herbivores.

The red abalone was selected for the present study because the range of colors displayed in shells is appreciable. Also minute, juvenile and young adult individuals were easily obtained in the required numbers.

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Materials & Methods

Specimens of Haliotis rufescens were collected, using SCUBA {Self Contained Underwater Breathing Apparatus}, at depths ranging from 40 to 80 feet in waters near La Jolla, California. Greatest numbers of small specimens (1.1 to 25.0 mm. in length) were found within holdfasts of the giant kelp, Macrocystis pyrifera (Linnaeus) Agardh, 1771. Larger individuals were commonly taken from beneath rocks. Kelp plants torn from the bottom and washed ashore by storms often yielded minute abalones in large numbers. As many as 23 specimens were retrieved from a single beached holdfast. Interestingly, the abalones collected from holdfasts were largely of the species H. rufescens, though occasionally H. corrugata Gray, 1828, and H. assimilis Dall, 1878, were taken. Only among specimens less than 3 mm. long was there any confusion as to species. Identification of smaller individuals was made by comparison with a carefully graded series of juvenile shells of each locally occurring abalone species.

Sizes of experimental animals ranged from 4 to 120 mm. in shell length. The smallest were maintained in one-quart polyethylene containers perforated with numerous holes $\frac{1}{8}$ inch in diameter and submerged in a wooden frame rack in circulating aerated sea water. The largest animals were held in 100-gallon concrete tanks similarly supplied with sea water. Low light intensities were maintained in the laboratory at all times precluding adventitious growth of algae.

Food consisted primarily of a variety of species of marine algae representing the brown, red and green algal classes. On several occasions such foreign materials as boiled potato, carrot, and yam were given.

Feeding experiments were conducted throughout one year during which time over 50 abalone were held for varying periods of time on restricted diets.

Results

Shells of juvenile Haliotis rufescens collected from holdfasts of Macrocystis were purely white, pale green or, when found in holdfasts with epiphytically growing red algae, were par-

tially red. Predominantly red-shelled specimens were collected about rocks which supported red algae.

In the laboratory a wide variety of red algal species (Rhodophyta) were provided as food with the consistent result that red pigmented shell was deposited. Pink color appeared in newly deposited shell after red algae had been given together with brown algae (Phaeophyta). When brown algae, green algae (Chlorophyta), or a number of foreign foods (e.g., potato or yam) had been given, the shell formed was either white, cream, or green, but never red. Results of all feeding experiments are given tabular summary below (see Table I).

Diets of brown algae, Macrocystis and Laminaria, were found to result in either white or green color in the newly formed shell. Other brown algae (e.g., Egregia and Eisenia), when ingested, influenced the formation of cream colored shell. Pelvetia fastigiata (Agardh) De Toni, 1895, gave origin to olive-green shell coloration.

Individuals fed alternately red and brown algae for one-month periods displayed similar growth rates on either diet. Shells of these abalones show alternate banding of red and white. It is also noteworthy that growth was substantial in abalone fed either potato or yam. Light green shell was produced on occasions when those diets were provided.

The multiple-colored specimen shown in the accompanying plate (Lower, right) is one of nu-

Table 1: Coloration of shell (ostracum) secreted by *Haliotis rufescens* on restricted diets

Diet	Color of Shell Produced	Number of Observations
Rhodophyta (Red Algae)		
Pterocladia pyramidale	red	12
Plocamium pacificum	red	20
Gelidium purpurascens	red	6
Gelidium nudifrons	red	5
Gigartina spinosa	red	25
Gigartina californica	red	7
Gigartina canaliculata	red	8
Phaeophyta (Brown Algae)		
Macrocystis pyrifera	white or pale green	44
Laminaria farlowii	green	18
Egregia laevigata	white or cream	8
Eisenia arborea	cream	6
Pelvetia fastigiata	olive green	5
Chlorophyta (Green Algae)		
Ulva sp.	pale green	8
Miscellaneous		
Potato, boiled	pale green	6
Yam, boiled	pale green	6
Carrot, boiled	cream	4
Agar	cream	4

Explanation of Plate 6

Figure 1: "Normally" pigmented juvenile *Haliotis rufescens* collected from a kelp bed with a mixed benthic flora. Figure 2: White phase abalone collected from a holdfast of the giant kelp *Macrocystis pyrifera*. Figure 3: Multiple-colored specimen with bands formed as a result of restricted feeding in the laboratory. For convenience, diets and their respective color bands are listed in reverse order of their deposition: *Eisenia* (shell margin), cream; *Pterocladia*, red; Potato, green; Miscellaneous red algae, red; Potato, pale green; *Gigartina*, red; *Macrocystis*, pale green. For additional explanation of this specimen, see text.

(The scale adjacent to the specimens represents ten millimeters)

Figure 1

Figure 2

Figure 3